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INDICATOR DIAGRAMS FROM MACHINE TOOLS.

BY LESTER P. BRECKENRIDGE, INSTRUCTOR IN MECHANICAL ENGINEERING IN THE LEHIGH UNIVERSITY.

In connection with the subject of machine design it has always been a matter of some difficulty to predict with any certainty what forces the different parts of a machine must transmit.

The forces in action during the operation of the common machine tools, such as the drill press, lathe, planer, milling machine, slotter and shaper, are:

(*a*) Gravity.

(*b*) Inertia.

(*c*) Pressures due to the action of the tool in reducing the material operated upon to the desired shape.

The first force needs rarely to be considered except in the larger sizes of tools.

The second force is more frequently to be examined especially in any tools running at a high speed. The action of either of these forces may however easily be determined from the known weights, speeds and dimensions of the different parts of the machine.

Desiring to ascertain the intensity of the third force, the following means were adopted.

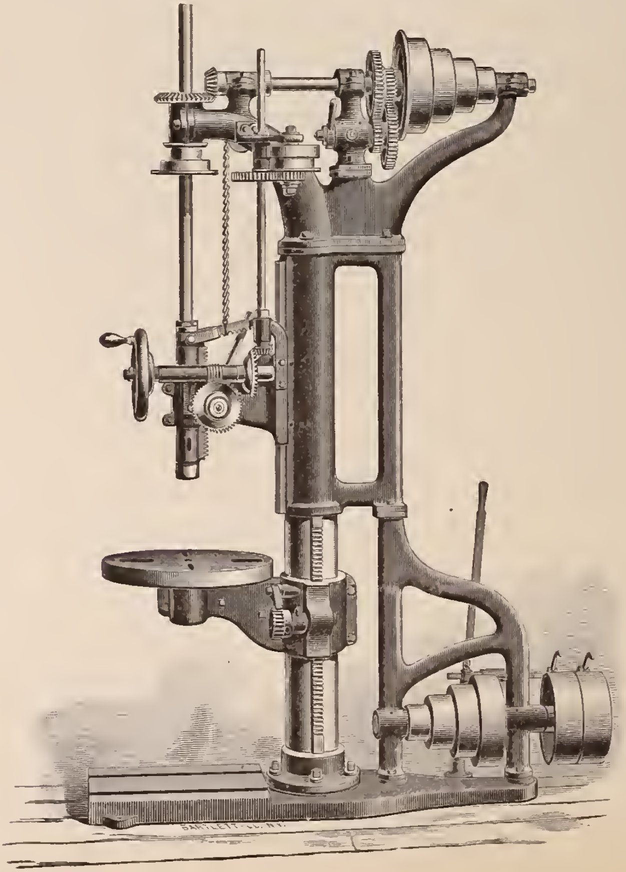
What pressure comes on a drill press table when drilling cast iron with a 1 inch twist drill? This question led to our experiments.

We went down to the machine shop of the Bethlehem Foundry and Machine Co. and obtained permission to use one of their drill presses.

We swung the table round to the side and set a pair of platform scales under the drill spindle, blocked up on the scales for about two feet, and drilled a ¾″ hole through a piece of cast iron. We found out that such an arrangement was of very little value because the scale beam beat back and forth between the stops like a clock pendulum with the weight taken off. We found out, however, that we had to deal with pressures of over 500 lbs.

It was at this point that the idea of using the indicator to furnish us with desired pressures, occured to us.

The drill press used in the experiments was made by Prentice Bros., of Worcester, Mass. It is shown in Fig: 1 below.



The leading dimensions of the drill are as follows:

Diameter of table, 20″.
Diameter of spindle, 1½″.
Speed of counter shaft, 250 revolutions per minute.
Diameter of pulleys on counter shaft, 11½″.
Width of belt to counter shaft, 3″.
Speed cones, 4 steps.

It has hand and power feed with a quick return lever, which may be used for light drilling. It is also back geared.

On the table of the drill press was placed the apparatus shown in Fig. 2. This consists of a cylinder of cast iron, flanged at the base and bored out to receive a plunger, the area of which was exactly 10 sq. in. Near the bottom of the plunger, three grooves $\frac{3}{32}$ in. deep and wide, were cut about ½ in. apart in order to prevent leakage of the oil which was placed in the cylinder below the plunger. Communication with the oil was then made to a steam gauge on one side and a Thompson indicator on the other as shown.

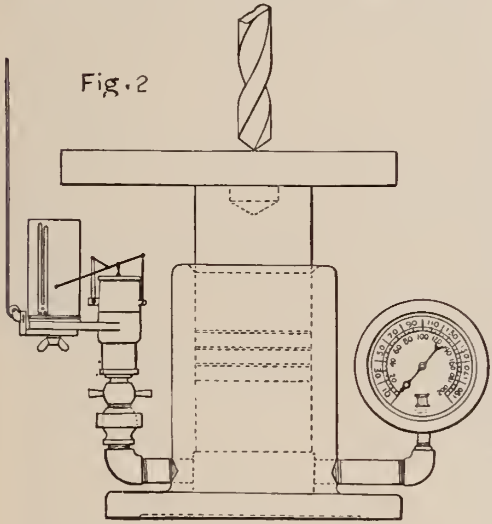


Fig. 2

The plunger was 6″ long, and when in use was allowed to project about 2″ above the top of the cylinder. The piece to be drilled was placed on the plunger.

The steam gauge used was tested by comparison with a standard gauge kept for the purpose and also by placing known weights upon the plunger.

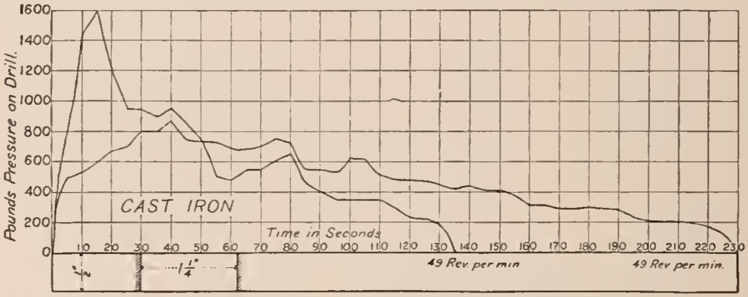
The plates drilled were cast for these experiments and were of the following thicknesses ½″, 1″, 1⅛″, 2″. Some of the plates were planed on one side, some on both sides, some not at all.

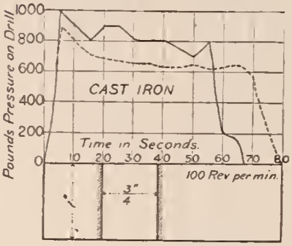
In connection with each hole drilled, the following data was obtained:

1 Diameter of drill.
2 Revolutions per minute of drill.

3 Depth of hole drilled in inches.
4 Time of drilling.
5 Kind of material drilled.
6 Character of feed used.
7 Gauge pressure in pounds every 5 seconds.

We experimented with Morse taper shank twist drills of the following sizes: ¼″, ½″, ¾″, 1″ and 1¼″. They were sharpened upon a twist drill grinder and the iron drilled was of a hardness 4 on a scale of 10, where 10 represents very hard cast iron.

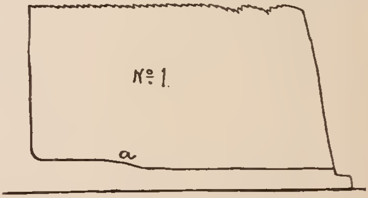


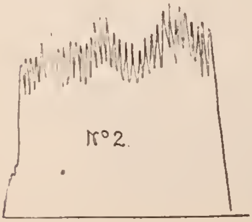


The total number of holes drilled was 143.

With ¼ in. drill, 53
" ½ in. " 45
" ¾ in. " 23
" 1 in. " 12
" 1¼ in. " 10

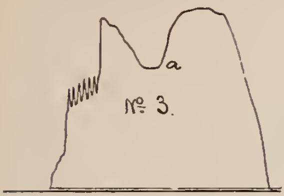
The cord from the paper drum of the indicator was taken up to the hub on the end of the shaft carrying the quick return lever and properly attached so that the length of the card represents the depth of hole drilled to some enlarged scale. A few of the cards are shown by 1 to 8; for data see page 6.





The experiments made by reading the gauge every 5 seconds were plotted after the manner shown in first two cuts on this page.

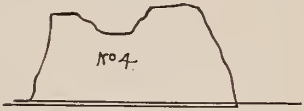
The speed at which the drills were run was determined from the following formulæ:



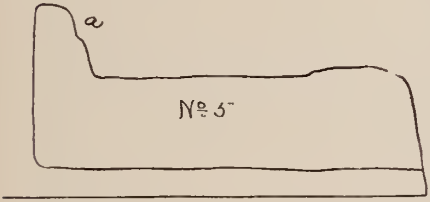
For wrought iron ND= 60.
" cast " ND= 80.
" brass ND=100.

in which N=the number of revolutions per minute of the drill, and D=the diameter of drill in inches.

This corresponds to a cutting speed at the circumference of the drill of

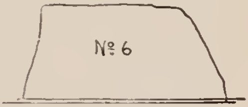


15.7 feet per minute for wrought iron.
20.9 " " " " cast "
26.2 " " " " brass.



It was not always possible to run the drills at the desired speed, but that speed of the drill press was used which came nearest to the desired speed.

Table I contains some of the experiments made by observations of the steam gauge, including all the data except the pressures, which space at this time will not allow. Columns 5 and 6 are deduced from the observed data, and are of particular interest in connection with the subject of machine design.



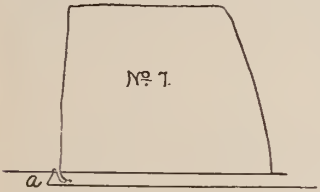
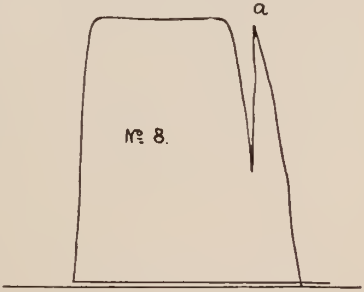


Table II is a record of the best time made in drilling different holes, all in cast iron; also of the maximum pressures occurring between the drill and the pieces drilled. In most of the holes drilled by power, the drill was started in by hand feed and the power feed was thrown out before the drill showed through in the case of the small drills.



These experiments will be continued during the present year, and the methods applied to other machine tools so that indicator cards may be taken from them, and a better understand-

ing obtained of the forces with which we have to deal in designing them. The following data refer to the indicator diagrams, Nos. 1 to 8.

No. 1. ¼″ drill, 194 R. P. M., 12 spring, 1⅛″ depth of hole, lever feed.

No. 2. ½″ drill, 175 R. P. M., 40 spring, 1⅛″ depth of hole, worm feed by hand.

No. 3. ½″ drill, 175 R. P. M., 60 spring, 1⅛″ depth of hole, worm feed by power and hand.

No. 4. ½″ drill, 175 R. P. M., 60 spring, 1⅛″ depth of hole, power feed.

No. 5. ½″ drill, 175 R. P, M., 30 spring, 1⅛″ depth of hole, power feed.

No. 6. ½″ drill, 175 R. P. M., 60 spring, 1″ depth of hole, power feed.

No. 7. ½″ drill, 175 R. P. M., 60 spring, 1⅛″ depth of hole, power feed.

No. 8. ½″ drill, 175 R. P. M., 40 spring, 1⅛″ depth of hole, power feed.

The solution to the problem which it was desired to solve will be found in the last two columns of Table II. Besides solving the problem before us, we have also some data now at hand which will enable us to derive formulæ showing the relation between the mean pressure on the drills and the time in seconds occupied in drilling, for a given speed of drill.

It has been found for this relation that the product of the two variables is for all practical purposes a constant. This may be seen by inspection of the two cuts on Page 4. The next step will be to formulate this relation for the different sizes of drills.

Referring to "*a*," Card No. 1, the slight fall in the back pressure line was due to the removal of the workman's hands from the workpiece when the drill was about half way out.

L. P. Breckenridge.

TABLE I.—¼ INCH DRILL.

No. for Reference.	Depth of Hole Drilled.	Time of Drilling.		Revolutions per Minute.	Time of Drilling 1 inch of Depth.		Advance per 100 Revolutions.	Character of Feed.	REMARKS.
	Inches.	Min.	Sec.		Min.	Sec.	Inches.		
1	½	0	17	295	0	34	.870	Power.	Cast Iron, unfinished.
2	½	0	16	295	0	32	.877	Power.	Cast Iron, unfinished.
3	½	0	25	294	0	50	.408	Hand by Lever.	Cast Iron, unfinished.
4	½	0	21	294	0	42	.485	Hand by Lever.	Cast Iron, unfinished.
5	½	0	20	294	0	40	.510	Hand by Lever.	Cast Iron, unfinished.
6	½	0	14	294	0	28	.757	Hand by Lever.	Cast Iron, unfinished.
7	1	0	36	292	0	36	.570	Power.	Cast Iron, unfinished.
8	1	0	35	292	0	35	.587	Power.	Cast Iron, unfinished.
9	1	0	33	292	0	33	.622	Power.	Cast Iron, unfinished.
10	1	0	43	294	0	43	.475	Hand by Worm.	Cast Iron, planed side down.
11	1	0	41	294	0	41	.498	Hand by Worm.	Cast Iron. planed side down.
12	1	0	29	294	0	29	.704	Hand by Lever.	Cast Iron, planed side down.
13	1⅛	0	43	293	0	38.2	.536	Hand by Lever.	Cast Iron, unfinished.
14	1⅛	0	38	293	0	33.8	.606	Hand by Lever.	Cast Iron, unfinished.
15	1⅛	0	34	295	0	30.2	.674	Hand by Lever.	Cast Iron, unfinished.
16	1⅛	0	51	298	0	45.3	.444	Hand by Worm.	Cast Iron, unfinished.
17	1⅛	0	49	293	0	43.6	.470	Hand by Worm.	Cast Iron, unfinished.
18	1⅛	0	40	294	0	35.6	.573	Hand by Worm.	Cast Iron, unfinished.
½ INCH DRILL.									
1	½	0	43	100	1	26	.696	Power.	Cast Iron, unfinished.
2	½	0	38	100	1	16	.788	Power.	Cast Iron, unfinished.
3	½	0	33	100	1	06	.907	Power.	Cast Iron, unfinished.

½ INCH DRILL—CONTINUED.

No. for Reference.	Depth of Hole Drilled.	Time of Drilling.		Revolutions per Minute.	Time of Drilling 1 inch of Depth.		Advance per 100 Revolutions.	Character of Feed.	REMARKS.
	Inches.	Min.	Sec.		Min.	Sec.	Inches.		
4	½	0	32	100	1	04	.935	Power.	Cast Iron, unfinished.
5	½	0	40	102	1	20	.735	Hand by Worm.	Cast Iron, unfinished.
6	½	0	37	102	1	14	.795	Hand by Worm.	Cast Iron, unfinished.
7	½	0	25	102	0	50	.850	Hand by Worm.	Cast Iron, unfinished.
8	½	0	24	160	0	48	.780	Hand by Worm.	Cast Iron, unfinished.
9	½	0	21	160	0	42	.892	Hand by Worm.	Cast Iron, unfinished.
10	1	0	34	165	0	34	1.069	Power.	Cast Iron, bottom side planed.
11	1	0	30	165	0	30	1.212	Power.	Cast Iron, bottom side planed.
12	1	0	55	180	0	55	.606	Hand by Worm.	Cast Iron, bottom side planed.
13	1	0	45	180	0	45.	.741	Hand by Worm.	Cast Iron, bottom side planed.
14	1⅛	0	40	165	0	35.6	1.021	Power.	Cast Iron, unfinished.
15	1⅛	0	36	165	0	32.0	1.136	Power.	Cast Iron, unfinished.
16	1⅛	0	57	165	0	50.7	.717	Hand by Worm.	Cast Iron, unfinished.
17	1⅛	0	47	165	0	41.8	.870	Hand by Worm.	Cast Iron, unfinished.
¾ INCH DRILL.									
1	½	0	45	100	1	30	.667	Hand by Worm.	Cast Iron, unfinished.
2	½	0	45	100	1	30	.667	Power.	Cast Iron, unfinished.
3	½	0	42	100	1	24	.717	Power.	Cast Iron, unfinished.
4	½	0	38	100	1	16	.792	Hand by Worm.	Cast Iron, unfinished.
5	1	1	23	100	1	23	.726	Power.	Cast Iron, unfinished.
6	1	1	20	100	1	20	.753	Power.	Cast Iron, unfinished.
7	1	1	18	97	1	18	.791	Hand by Worm.	Cast Iron, unfinished.

¾ INCH DRILL—CONTINUED.

No. for Reference.	Depth of Hole Drilled. Inches.	Time of Drilling. Min.	Time of Drilling. Sec.	Revolutions per Minute.	Time of Drilling 1 inch of Depth. Min.	Time of Drilling 1 inch of Depth. Sec.	Advance per 100 Revolutions. Inches.	Character of Feed.	REMARKS.
8	1	1	15	99	1	15	.808	Hand by Worm.	Cast Iron, unfinished.
9	1	1	06	97	1	06	.935	Hand by Worm.	Cast Iron, unfinished.
10	1⅛	2	10	102	1	56	.507	Hand by Worm.	Cast Iron, unfinished.
11	1⅛	1	45	102	1	33	.633	Hand by Worm.	Cast Iron, unfinished.
12	½	1	41	102	3	22	.291	Hand by Worm.	Rolled Wrought Iron.
13	½	1	33	101	3	06	.316	Hand by Worm.	Rolled Wrought Iron.
14	½	1	27	92	2	54	.376	Hand by Worm.	Rolled Wrought Iron.
15	½	1	15	101	2	30	.397	Hand by Worm.	Rolled Wrought Iron.
16	½	0	52	102	1	44	.566	Hand by Worm.	Rolled Wrought Iron.
17	½	0	47	103	1	34	.618	Hand by Worm.	Rolled Wrought Iron.
1 INCH DRILL.									
1	½	2	54	53	5	48	.325	Hand by Worm.	Rolled Wrought Iron.
2	½	2	10	53	4	20	.436	Hand by Worm.	Rolled Wrought Iron.
3	½	1	25	53	2	50	.666	Hand by Worm.	Cast Iron, unfinished.
4	½	1	21	53	2	42	.699	Hand by Worm.	Cast Iron, unfinished.
5	½	1	06	100	2	12	.454	Hand by Worm.	Cast Iron, unfinished.
6	½	0	54	100	1	48	.544	Power.	Cast Iron, unfinished.
7	½	0	48	100	1	36	.624	Hand by Worm.	Cast Iron, unfinished.
8	½	0	47	100	1	34	.637	Power.	Cast Iron, unfinished.
9	1	1	47	98	1	47	.571	Hand by Worm.	Cast Iron, bottom side planed.
10	1	1	40	97	1	40	.617	Power.	Cast Iron, unfinished.
11	1	1	32	97	1	32	.671	Power.	Cast Iron, bottom side planed.
12	1⅛	1	43	100	1	32	.651	Hand by Worm.	Cast Iron, unfinished.

1¼ INCH DRILL.

No. for Reference.	Depth of Hole Drilled.	Time of Drilling.		Revolutions per Minute.	Time of Drilling 1 inch of Depth.		Advance per 100 Revolutions.	Character of Feed.	REMARKS.
	Inches.	Min.	Sec.		Min.	Sec.	Inches.		
1	½	4	00	49	8	00	.255	Hand by Worm.	Cast Iron, unfinished.
2	½	3	50	49	7	40	.266	Hand by Worm.	Cast Iron, unfinished.
3	½	2	15	49	4	30	.453	Hand by Worm.	Cast Iron, unfinished.
4	½	1	42	49	3	24	.600	Hand by Worm.	Cast Iron, unfinished.
5	1	4	45	49	4	45	.430	Slow Power.	Cast Iron, bottom side planed.
6	1	4	37	49	4	37	.442	Hand by Worm.	Cast Iron, unfinished.
7	1	4	12	50	4	12	,476	Slow Power.	Cast Iron, bottom side planed.
8	1	3	24	49	3	24	.600	Fast Power.	Cast Iron, unfinished.
9	1	3	10	49	3	10	.644	Hand by Worm.	Cast Iron, bottom side planed.
10	1⅛	2	24	96	2	08	.488	Hand by Worm.	Cast Iron, unfinished.

TABLE II.

Diameter of Drill.	Depth of Hole Drilled.	Shortest time required to Drill when Feeding By Power.		By Hand.		Maximum Pressure on Drill while Drilling at Start.	Maximum Pressure on Drill while Drilling with full Diameter of Drill.
Inches.	Inches.	Min.	Sec.	Min.	Sec.		
¼	½	0	16	0	14	400 lbs.	350– 400 lbs.
¼	1	0	33	0	29		
½	½	0	32	0	21	900 lbs.	800– 900 lbs.
½	1	0	30	0	45		
¾	½	0	42	0	38	1100 lbs.	800– 900 lbs.
¾	1	1	20	1	06		
1	½	0	47	0	48	1450 lbs.	1000–1150 lbs.
1	1	1	32	1	47		
1¼	½	—	—	1	42	1800 lbs.	1000–1150 lbs.
1¼	1	3	24	3	10		

THE LOCATION OF EASEMENT CURVES.

BY FRED. P. SPALDING, '80, INSTRUCTOR IN CIVIL ENGINEERING IN THE LEHIGH UNIVERSITY.

The necessity for using some form of easement curve, to connect the circular arcs upon railroad lines with the tangents, is now very generally recognized. Their adoption, however, has been greatly retarded by the difficulty met in attempting to reduce a satisfactory curve to a convenient form for ready use in the field.

Two methods of location are at present in use; first, by Froude's formulas for the cubic parabola as given by Rankine, the determination of the ordinates for setting out being made for each curve directly from the formulas; and second, the method of the railroad spiral as given by Searles and others, in which practically the same curve is located by means of deflection angles corresponding to various fixed chord lengths, the curve being varied by changing the chord length.

The object of this paper is to show how by a simple tabulation the cubic parabola may be readily located in practice, either by ordinates or deflection angles, without the necessity of making calculations from formulas for each case, but at the same time allowing the use of chords of any lengths and the placing of stations wherever desired.

The formulas for this curve as given by Rankine are

$$y = \frac{4\,s\,x^3}{l^3} \quad (1) \quad \text{and} \quad s = \frac{l^2}{24R} \quad (2)$$

in which s is the shift or offset BC (Fig. 1) of the circular arc from the tangent, l is the length AD (Fig. 1) of the easement curve, R is the radius of the circular arc, and y is the perpendicular offset from the tangent or from the circular arc to the easement curve, at any point distant x from the junction of the easement curve with the tangent or circular arc.

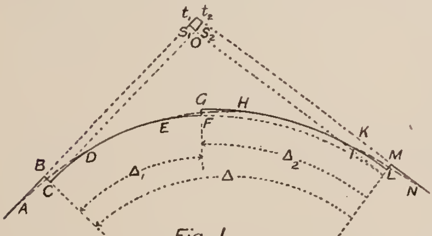


Fig. 1.

If it be desired to connect two curves of different degrees, the same form of easement curve may be employed, using only that portion of it which lies between the points where its radius of curvature equals the radii of the arcs to be connected. For this

case, equation (1) applies directly, while for the value of the shift (2) becomes

$$s = \frac{l^2 (R_1 - R_2)}{24 R_1 R_2} \quad (3)$$

in which R_1 and R_2 are the radii of the circular curves.

LOCATION BY ORDINATES.

In order to locate an easement curve by this method, it is necessary to assume the value of either the length or the shift and calculate the other from formula (2) or (3). The shift may be fixed by topographical considerations, or the length may be determined by fixing the value for the ratio of the change in rail elevation to the length, authorities differing as to the best value to use for this ratio, but probably any value above the 1 in 300 recommended by Froude will give good results. Having thus found the value for the shift, it is to be laid off from the tangent toward the center of the proposed curve, and the circular arc run in from a parallel tangent at that distance from the main one. In other words, in locating a line upon which easement curves are to be used, the circular curves, instead of being placed in the usual manner tangent to the straight portions of the track, should be made tangent to parallel lines at a distance s from the main tangents, and in the same way the arcs of a compound curve should not be tangent to each other at the *P. C. C.*, but the arc of smaller radius should begin at a point on the common radial line distant s inward from the end of the larger arc.

The half-length of the easement curve is then laid off from the *P. C.* on the circular arc, and the point D (Fig. 1) so found will be the junction of the two curves; the half-length is also laid off on the main tangent from a point opposite the *P. C.* (B, Fig. 1) to find the point of tangency A (Fig. 1) of the easement curve.

Having determined these points, different values of x less than $\frac{l}{2}$ substituted in formula (1) will give values of y to be laid off from points distant x from D on the circle, and from A on the tangent, to determine points on the easement curve.

Tables may now be constructed on these formulas which will give directly the value of the ordinates to be used in placing the curve on the ground, and as experience has shown that comparatively few variations will be necessary to meet all

cases in practice, such tables need not be very extended to answer all requirements.

In order to construct such a table, suppose that the curvature is to increase 1° for every 50 *ft.* of distance, then for a 10° curve, $l = 500$ *ft.* and $s = \frac{l^2}{24R} = 18.16$ *ft.*; substituting these values in (1), if $x = 10$ *ft.*, $y = .000581$ *ft.* To find other values of y corresponding to different values of x, we notice that y varies as the cube of x, and thus construct the last column of Table I.

In order to extend the table to other curves in which the curvature varies differently, we notice that, combining formulas (1) and (2), y varies as $\frac{R}{l}$ for x constant, or inversely as the ratio between length and increase of curvature.

In the table, the offset is given for every 10 *ft.* of length. Intermediate values may be found by interpolation, without sensible error.

To illustrate the use of the table in locating a curve, suppose that two tangents are to be connected by a compound curve composed of an arc of 5° and one of 8° curvature, and that the changes of radius are to be eased by curves, in which the curvature increases 1° for every 40 *ft.* of distance from the tangent.

First the circular curves must be located as shown by the full lines (Fig. 1) with the proper shift from the tangents and from each other.

For an increase of curvature of 1° in 40 *ft.*, the length of easement curve for an 8° will be 320 *ft.*

When $x = \frac{l}{2}$ (formula 1), $y = \frac{s}{2}$, and going into the table with $x = \frac{l}{2} = 160$, we find $y = 2.97 = \frac{s}{2}$, hence $BC = s = 5.94$ *ft.* In the same way $ML = s = 1.46$ *ft.* may be found for the 5°. For the connection between the two circular arcs, $l =$ the difference of lengths of the curves required to connect the two arcs with tangent $= 320 - 200 = 120$ *ft.* and as before $\frac{s}{2} = .15$ *ft.* may be taken from the table.

Now to locate the curve AD, suppose that the *P.C.* of the circular arc comes at sta. 10 + 65 and that it is desired to mark 50 *ft.* stations on the easement curve, these stations having first been located on the tangent AB and the arc CD. As the half-length of the easement curve is 160 *ft.* the *P.E.C.*, or point where the ease-

ment curve leaves the tangent will be at sta. 9+05. The quantities necessary to lay out the easement curve may then be tabulated as follows, taking values of y to nearest tenth foot.

Sta. 9+05	*P.E.C.*	$x = 0$,	$y = 0.0$,	Measured from tangent.
9+50		$x = 45$,	$y = 0.1$,	" " "
10		$x = 95$,	$y = 0.6$,	" " "
10+50		$x = 145$,	$y = 2.2$,	" " "
10+65	*P.C.*	$x = 160$,	$y = 3.0$,	" " "
11		$x = 125$,	$y = 2.4$,	" " Curve *CD*.
11+50		$x = 75$,	$y = 0.3$,	" " "
12		$x = 25$,	$y = 0.0$,	" " "
12+25	*P.O.*	$x = 0$,	$y = 0.0$,	" " "

The location of this curve is thus seen to be a very simple matter; calculations for the circular arcs may be made in the usual manner, and the use of the easement curve introduces no new element into their location, save the necessity of laying them tangent to lines parallel to the main tangents.

The tangent distance on main tangent to *P.E.C.* may be found from the formula $T_E = T + \frac{l}{2} + t$, in which T is the tangent distance for the curve as ordinarily run, $\frac{l}{2}$ the half-length of the easement curve, and t a correction due to shifting the point of intersection (see Fig. 1). For a simple curve with the same shift at both ends $t = s \tan \frac{1}{2} \Delta$. For a simple curve with different values of s at the two ends, $t_1 = \frac{s_2}{\sin \Delta} - s_1 \cot \Delta$ and $t_2 = \frac{s_1}{\sin \Delta} - s_2 \cot \Delta$. For a compound curve, if s_3 be shift between circular arcs, s_2 that of the curve of larger, and s_1 of the curve of smaller radius from the tangent, $t_1 = \frac{s_2 + s_3 \cos \Delta_2}{\sin \Delta} - s_1 \cot \Delta$ and

$$t_2 = \frac{s_1}{\sin \Delta} - (s_2 + s_3 \cos \Delta_2) \cot \Delta + s_3 \sin \Delta_2.$$

LOCATION BY DEFLECTION ANGLES.

If the values of x in Table I be supposed to be measured on chords of the easement curve, and if a be the angle between the tangent and the chord to any point distant x from the *P.E.C.*, then $\sin a = \frac{y}{x}$, and if a table of the values of a for each curve be made, the curve may be located on the ground in the ordinary manner by deflections from the tangent.

To construct this table, take a value of y and divide it by the

corresponding value of x, and find from a table of sines the angle of deflection, then since y varies as the cube of x, $\frac{y}{x}$ varies as the square of x, and as for small angles the sine is approximately as the angle, the various angles may be taken as varying with the squares of their distances. In this manner any column of Table II may be constructed, then any other column may be found, as in the case of the ordinates in Table I, by considering that for constant values of x, $\frac{y}{x}$ varies inversely as the ratio between the length of curve and the change in curvature.

As the length of easement curve is not exactly equal to the sum of the lengths measured on the tangent and circular arc, a correction must in some cases be applied, when the curve is to be located by this method. This correction which we will call z, is to be subtracted from $\frac{l}{2}$, to determine the distance to be measured back on the tangent from the *P.C.* to find the *P.E.C.* Applying this correction to the formula for tangent distance we have $T_E = T + t + \frac{l}{2} - z$. Values of z are given in Table III, found by calculating the co-ordinates of the ends of the easement curve by the two lines.

In order to lay out a curve by this method, we first locate the *P.E.C.*, and placing the instrument at that point, turn off the deflections and lay out the curve by chords of any desired length, interpolating between the numbers in the table for the angle to any point not given. To pass from a circular arc to the tangent, or to an arc of greater radius, the *P.O.*, or point of osculation, is located at a distance $\frac{l}{2}$ from the *P.T.*, and then as the deviation of the easement curve from the circular arc is the same as from the tangent, the deflection to any point of the easement curve distant x from the *P.O.* is equal to the deflection for the circular arc for the same distance *minus* the deflection for that distance as given in Table II, or in passing from a curve of larger to one of smaller radius, the tabular deflection must be added to the circular deflection.

As an illustration of this method suppose that it be required to locate the curve of Fig. 1 by means of deflection angles. It will not be necessary in this case as in the former one to first locate the circular arcs, but, having found the *P.E.C.*, set the instrument over that point, turn off the deflections, and run in the curve in the ordinary manner.

The deflections for the first easement curve may be taken directly from Table II, as given below,

Sta. 9+05 *P.E.C.*	$x=$ 0		
9+50	$x=$ 45,	$a=0°05'$	
10	$x=$ 95,	$a=$ 22'	
10+50	$x=$ 145,	$a=$ 52'	
11	$x=$ 195,	$a=1°35'$	
11+50	$x=$ 245,	$a=2°30'$	
12	$x=$ 295,	$a=3°37'$	
12+25 *P.O.*	$x=$ 320,	$a=4°16'$	

Having located the *P.O.* and set the instrument there, we turn to tangent by deflecting from a backsight on the *P.E.C.* an angle equal to twice the last forward deflection, 2 (4° 16') = 8° 32'. In other words, the angle between the tangent at any point of the easement curve, and the chord connecting that point with the *P.E.C.* is equal to twice the angle between the tangent at the *P.E.C.* and the same chord.

To locate the easement curve connecting the circular arcs, having located the first arc *DE*, (Fig. 1) and found the *P.O.* (*E*) at which the second easement curve begins, suppose this point to come at station 17+22.5; the deflections for this easement curve from the circular arc *EF* will then be the same as those of the first curve from the tangent *AB*, or the deflections from the curve *EH* from the tangent at *E*, will equal the deflections for the arc *EF*, minus the deflections from Table II for the easement curve, and may be tabulated as follows:

Sta. 17+22.5 *P.O.*	$x=$ 0		
17+50	$x=$ 27.5,	deflection	$=1°06'-0°02'=1°04'$
18	$x=$ 77.5,	"	$=3°06'-0°15'=2°51'$
18+42.5 *P.O.*	$x=$120.0,	"	$=4°48'-0°36'=4°12'$

To find the tangent at 18+42.5 (*P.O.*), turn from the last chord an angle = deflection for 120' of 8° curve, (4°48') *minus* twice (deflection for 120' of easement curve), ($2\times36'=72'$)$=3°36'$, or this angle may be found thus; deflection for 120' of 5° curve, (3°00') *plus* deflection for 120' of easement curve, (36') = 3°36'.

In the same manner having run the 5° circular arc, we can tabulate the deflections necessary to connect it with the tangent, supposing the *P.O.* to be at sta. 23+13.5

23+13.5 *P.O.*	$x=0$	
23+50	$x=$ 36.5,	deflection$=0°55'-0°03'=0°52'$

24	$x = 86.5$,	deflection	$=2^\circ 10' - 0^\circ 19' = 1^\circ 51'$
24+50	$x = 136.5$,	"	$=3^\circ 25' - 0^\circ 47' = 2^\circ 38'$
25	$x = 176.5$,	"	$=4^\circ 40' - 1^\circ 27' = 3^\circ 13'$
25+13.5 *P.E.T.*	$x = 200$,	"	$=5^\circ 00' - 1^\circ 40' = 3^\circ 20'$

Then turn to the tangent at *M*, by deflecting from the last chord, one-half the last deflection, $\frac{1}{2}(3^\circ 20') = 1^\circ 40'$ = the deflection for 200 ft. of the easement curve.

The deflection from the *P.E.C.* to any point x of the easement curve is equal to one-third of the deflection for the same length of the circular arc, whose radius is equal to the radius of curvature of the easement curve at the point x; also, the difference between the circular deflections at any two points of an easement curve, for a length equal to the distance between the points, is equal to three times the easement deflection for the same length.

In case it be necessary to set the instrument at any intermediate point upon the curve, this enables us to readily find the deflections for the circular arc at that point. Thus, if we desire to set the instrument at station 24 in the above example, we first turn to tangent at 24 by deflecting $2^\circ 10' - 2 \times 19' = 1^\circ 32'$ from the last chord.

Then the deflection for 86.5 *ft.* of the circular arc, whose radius equals the radius of curvature of the easement curve at station 24 is $2^\circ 10' - 3 \times 19' = 1^\circ 13'$, and the deflection for 50 *ft.* is $\frac{50}{86.5}(1^\circ 13')$ $=42'$ or, as the point 24 is 113.5 *ft.* on the easement curve from the tangent, easement deflection for 113.5 *ft.* is 32′ (Table II), and $32' \times 3 \times \frac{50}{113.5} = 42'$.

Then the deflections from tangent at 24 for the remainder of the curve would be

Sta. 24	$x = 0$,		
24+50	$x = 50$,	deflection	$= 42' - 06' = 0^\circ 36'$
25	$x = 100$,	"	$=1^\circ 24' - 25' = 0^\circ 59'$
25+13.5 *P.E.T.*	$x = 113.5$,	"	$=1^\circ 36' - 32' = 1^\circ 04'$

As will be seen by an inspection of the tables, the few curves tabulated afford considerable range for choice of a curve for any particular case, and will give considerable elasticity to the work of placing the location by allowing the use of various shifts. Tables affording a much larger choice may readily be constructed, and will occupy but a small space while answering all the requirements of any practical case.

SPECIAL CASES.

It is frequently necessary to replace circular curves already in use, by others connecting the same tangents and passing through certain points whose positions are known. All such cases may be met by the foregoing methods, the solution in each case varying with the data given.

As an illustration take one of the most common cases. Let

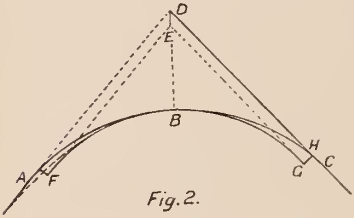


Fig. 2.

ABC (Fig. 2) be an 8° circular curve 700 ft. long, which is to be replaced by a new circular arc, passing through the same vertex (*B*) and joined to the same tangents by easement curves in which the curvature change 1° for each 30 *ft.* of distance. The shift for the 8° curve from Table I is 3.3 *ft.*, but the new arc will be of less radius than the 8° and the shift greater; assume it at 4.0 *ft.*, then the external distance (*DB*) of the 8° curve $= R.\ ex.\ sec\ \frac{1}{2}\Delta, = 716.779 \times .13257 = 95.02$ *ft.*

$DE = GH\ sec\ \frac{1}{2}\Delta = s\ sec\ \frac{1}{2}\Delta.$

BE (the external distance for the new arc) $= BD - DE = 95.02 - 4 \times 1.13257 = 90.49$ *ft.*, and the radius of the new arc $= \frac{BE}{ex.\ sec\ \frac{1}{2}\Delta} = \frac{90.49}{.13257} =$ 682.6 *ft.* or the rate of curvature of the new arc is 8°24′.

The length of easement curve to vary 1° in 30 *ft.* is then 252 *ft.*, the half-length 126 *ft.*, and (from the table) the half-shift is 1.95 or $s = 3.9$, which shows that our assumption of 4.0 *ft.* for the shift is sufficiently accurate; in case it were not, it would be necessary to try a new one.

Now from *B*, the 8°24′ curve may be located ending at *F* and *G*, or the tangent distance may be computed from the formula, and the *P.E.C.* located after which the curve may be placed by the use of the tables as in the former cases.

If it be desired to shift the vertex of the new curve any distance either outward or inward from the original curve, it will simply be necessary to subtract such distance from or add it to the external distance in finding the radius of the new curve.

TABLE I.—ORDINATES FOR LOCATING THE CUBIC PARABOLA.

Values of x.	CURVATURE CHANGES 1° FOR EVERY						
	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet
10 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.
20 "	0.01 "	0.01 "	0.01 "	0.01 "	0.01 "	0.00 "	0.00 "
30 "	0.04 "	0.03 "	0.03 "	0.02 "	0.02 "	0.02 "	0.02 "
40 "	0.09 "	0.07 "	0.06 "	0.05 "	0.05 "	0.04 "	0.04 "
50 "	0.18 "	0.14 "	0.12 "	0.10 "	0.09 "	0.08 "	0.07 "
60 "	0.31 "	0.25 "	0.21 "	0.18 "	0.15 "	0.14 "	0.13 "
70 "	0.50 "	0.40 "	0.32 "	0.28 "	0.25 "	0.22 "	0.20 "
80 "	0.74 "	0.60 "	0.49 "	0.42 "	0.37 "	0.33 "	0.30 "
90 "	1.06 "	0.85 "	0.70 "	0.60 "	0.53 "	0.47 "	0.42 "
100 "	1.45 "	1.16 "	0.97 "	0.83 "	0.73 "	0.65 "	0.58 "
110 "	1.93 "	1.55 "	1.29 "	1.10 "	0.96 "	0.86 "	0.77 "
120 "	2.51 "	2.00 "	1.67 "	1.43 "	1.25 "	1.12 "	1.00 "
130 "	3.19 "	2.56 "	2.13 "	1.83 "	1.60 "	1.42 "	1.28 "
140 "	3.98 "	3.20 "	2.66 "	2.29 "	2.00 "	1.77 "	1.60 "
150 "	4.90 "	3.92 "	3.27 "	2.80 "	2.45 "	2.18 "	1.96 "
160 "				3.39 "	2.97 "	2.64 "	2.38 "
170 "				4.08 "	3.57 "	3.17 "	2.85 "
180 "				4.84 "	4.24 "	3.76 "	3.38 "
190 "				5.69 "	4.98 "	4.43 "	3.98 "
200 "				6.64 "	5.81 "	5.16 "	4.64 "
210 "						5.98 "	5.38 "
220 "						6.87 "	6.19 "
230 "						7.85 "	7.07 "
240 "						8.92 "	8.03 "
250 "						10.09 "	9.08 "

TABLE II.—DEFLECTIONS FOR LOCATING THE CUBIC PARABOLA.

Values of x	CURVATURE CHANGES 1° FOR EACH						
	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.
10 feet.	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′
20 "	02	02	01	01	01	01	01
30 "	05	04	03	03	02	02	02
40 "	08	06.	05	04	04	03	03
50 "	13	10	08	07	06	06	05
60 "	18	15	12	10	09	08	07
70 "	25	20	16	14	12	11	10
80 "	32	26	21	19	16	14	13
90 "	40	32	27	23	20	18	16
100 "	50	40	33	29	25	22	20
110 "	1 00	48	40	34	30	27	24
120 "	12	58	48	41	36	32	29
130 "	25	1 08	56	49	42	38	34
140 "	38	18	1 05	56	49	43	39
150 "	52	30	15	1 04	56	50	45
160 "	2 08	42	25	13	1 04	57	51
170 "	25	56	36	23	12	1 04	58
180 "	42	2 10	48	33	21	12	1 05
190 "	3 00	24	2 00	43	30	20	12
200 "	20	40	13	54	40	29	20
210 "	40	56	27	2 06	50	38	28
220 "	4 02	3 14	41	17	2 01	47	37
230 "	25	32	56	31	12	58	46
240 "	48	50	3 12	45	24	2 08	55
250 "	5 12	4 10	28	59	36	19	2 05
260 "	38	30	45	3 13	49	30	15
270 "	6 05	52	4 03	29	3 02	42	26
280 "	32	5 14	21	44	16	54	37
290 "	7 00	36	40	4 00	30	3 07	48
300 "	7 30	6 00	5 00	17	45	20	3 00

TABLE II.—CONTINUED.

Values of x.	CURVATURE CHANGES 1° FOR EACH						
	20 feet.	25 feet	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.
310 feet.				4° 34′	4° 00′	3° 33′	3° 12′
320 "				43	16	48	25
330 "				5 11	32	4 02	38
340 "				30	49	17	51
350 "				50	5 06	32	4 05
360 "					24	48	19
370 "					42	5 04	34
380 "					6 01	21	49
390 "					20	38	5 04
400 "					40	55	20
410 "						6 13	36
420 "						32	53
430 "						41	6 10
440 "						7 10	27
450 "						30	45
460 "							7 03
470 "							22
480 "							40
490 "							8 00
500 "							20

TABLE III.—VALUES OF z.

MINUS CORRECTION FOR TANGENT DISTANCE OF EASEMENT CURVE LOCATED BY DEFLECTION ANGLES.

Degree of Curve.	CURVATURE CHANGES 1° FOR EACH						
	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.
6°					0.1 feet.	0.1 feet.	0.1 feet.
7°			0.1 feet	0.1 feet.	0.2 "	0.2 "	0.3 "
8°		0.1 feet.	0.2 "	0.3 "	0.4 "	0.5 "	0.6 "
9°	0.1 feet.	0.2 "	0.4 "	0.5 "	0.7 "	0.8 "	1.1 "
10°	0.2 "	0.3 "	0.6 "	0.8 "	1.0 "	1.3 "	1.7 "
11°	0.3 "	0.5 "					
12°	0.4 "	0.7 "					
13°	0.6 "						
14°	0.8 "						
15°	1.1 "						

FRED. P. SPALDING.

ALUMINUM BRONZE.

So universal is the use of iron in its various forms,—cast iron, wrought iron and steel,—that we cannot reasonably suppose that its place can ever be taken by any other material.

The only other known metal, which could, by any possibility, be substituted for it, is aluminum, but owing to the great expense of reducing this metal from its ores, its extensive use as a material for engineering construction would seem at present to be entirely precluded. Consequently iron is accepted as the most available of the metals for ordinary use, as it combines cheapness with its many excellent physical and mechanical properties. But while thus accepted, the fact remains, that for many purposes, particularly in machine construction, iron in any form is not suitable and in some instances cannot be employed at all. Its readiness to oxidize

is one great source of difficulty, as is also the fact that it is quickly corroded by acids, gases and impure water. It has been found best to use other metals for journal bearings and sliding faces, and in most cases, the metals so used are alloys; *e.g.*, brass, bronze and gun-metal.

These alloys are usually regarded as mechanical mixtures of the metals which compose them, and are made by fusing together their constituents in proper proportions. In chemical combinations of metals with non-metals, the metallic qualities and chemical properties of the substances which combine, are completely altered, and the resulting compound bears no resemblance to either. This is not generally the case with the alloys. The physical properties of the alloys are, however, sometimes quite different from those of the constituent metals, though the compounds formed are evidently not definite as in cases of simple chemical reactions. Good authorities think it probable that the force of chemical affinity performs some part in the formation of the alloy, although the exact nature of this action is not understood.

What has been stated in reference to these compounds is especially noticeable in the alloys of aluminum.

The most valuable and useful of these alloys is *aluminum bronze*, which is composed of copper and aluminum only, the standard grade or quality containing 90 per cent. of copper and 10 per cent. of aluminum. While ordinary bronzes are classed as mechanical mixtures, aluminum bronze seems to be truly "a chemical alloy," for its constituents appear to have a chemical affinity for each other. That this is true, is proved by the fact that the two metals unite when just melted, the heat evolved causing the temperature to rise so much that the crucible in which the melting is done becomes white hot. Another proof is furnished by the fact that the ingredients cannot be separated by remelting the alloy.

In a general way, aluminum is thought to improve the qualities of every metal to which it is added in small quantities. It increases the strength and lustre of the softer metals, and renders others much less liable to corrosion.

Prof. R. H. Thurston says in *Materials of Engineering:* "Aluminum is added to copper and to the bronzes and brasses with good results. The alloy consisting of 90 parts of copper and 10 parts aluminum may be worked cold or hot like wrought iron, but not welded. It has a tenacity of 100,000 pounds to the sq. inch.

It is hard, stiff and very homogeneous. It has been drawn into

wire, and is very ductile and malleable. It works well, casts well, holds a fine surface under the tool and when exposed to the weather, and is in every respect considered the best bronze yet known. Its high cost alone prevents its use in the arts."

At the time when this was written, the alloy could not be manufactured and sold for less than $5.00 per pound, but since Prof. Thurston's book was published, several methods of producing the bronze more cheaply have been discovered, and judging from the present outlook, it is destined to become of great importance.

The compound was discovered as early as 1856 by John Percy, but although its wonderful properties were soon recognized, it is only lately that it has been produced in appreciable quantities. The only extensive plant in this country for the manufacture of aluminum bronze is that of the Cowles Electric Smelting and Aluminum Company, of Lockport, New York.

In the *Railroad Gazette* for Oct. 21, 1887, the following notice is given concerning this new industry:

"The invention of the electric furnace by Messrs. E. H. and A. H. Cowles has brought on the market new varieties of copper, brass and iron alloys with aluminum which promise to have an increasing value for constructive purposes as the knowledge of their properties increases and the cost of production decreases. The Messrs. Cowles have taken advantage of the high heat developed by resistance to a strong current of electricity. Grains of corundum ($Al_2\ O_3$) are imbedded with copper in a cylinder of powdered charcoal to the ends of which are connected two carbon electrodes, the whole being surrounded with charcoal in a box of fire brick.

The resistance offered to the passage of the electric current fuses, and possibly volatilizes the aluminum in the emery, and it combines with the copper forming an alloy containing from 15 to 20 per cent. of aluminum. By using this alloy in the furnace instead of pure copper, an alloy richer in aluminum may be secured. When an alloy containing both aluminum and silicon is desired, clay is used in place of corundum, and for 'mitis' or steel castings, the copper is replaced by iron.

These bronzes melt at about 1700° *F.*, and as neither copper nor aluminum volatilizes except at extremely high temperatures, it is claimed that they can be repeatedly remelted without appreciable changes in their strength."

Those readers of the JOURNAL who are interested in these alloys

and wish to know more concerning the details of the process of manufacture, may find a very full and complete description in the work entitled *Aluminium*, by Mr. Joseph W. Richards, A. C. A brief account of the method of using the furnace is also given in a paper entitled " An Electrical Furnace for Reducing Refractory Ores," read before the American Institute of Mining Engineers, Sept. 16, 1885, at Halifax, Nova Scotia, by Prof. T. Sterry Hunt, of Montreal.

The Cowles Company publish a pamphlet entitled " *The Alloys of Aluminum and Silicon*," and the following facts concerning the properties, working qualities, and uses of the different grades of aluminum bronze have been obtained and condensed mainly from the statements of this pamphlet.

The 10 per cent. aluminum bronze possesses a deep golden color, and has a specific gravity of 7.7, or about the same as as iron. It has many remarkable characteristics. In tensile strength, the castings from this *A* grade, as it is called, run from 75,000 lbs. to 95,000 lbs. to the square inch with from 4 to 14 per cent. elongation. This may be compared with the following average ultimate tensile strength of metals and alloys as given in *Trautwine's Engineer's Pocket Book.*

	PER SQ. INCH.
Cast brass,	23,000 lbs.
Annealed brass wire,	49,000 "
Cast copper,	24,000 "
Annealed copper wire,	32,000 "
Average American cast iron,	16,000 "
Good wrought iron,	50,000 "
Best American wrought iron,	76,000 "
Malleable iron castings,	48,000 "
Rolled steel plates,	81,000 "
Average Bessemer ingots (cast steel),	63,000 "

" In resistance to compression, this metal equals the best cast steel; its transverse strength is about forty times greater than ordinary brass; its limit of elasticity is equal to that of the best grades of steel of the same tensile strength and elongation, forged, tempered and annealed; its ductility is about the same as that of the best grades of forged, tempered and annealed steel of the same strength."

A *special* grade is also made by the Cowles Company, which contains more aluminum than the *A* grade, having between 10 and

11 per cent. With more than 11 per cent. of aluminum, the bronze becomes brittle, so nothing higher than the *special* is made. The *special* grade is correspondingly higher than the *A* grade in tensile, transverse, and torsional strength, and its elastic limit is higher. It offers a greater resistance to compression than the *A* grade, but its ductility or elongation is less, ranging from nothing up to 8 per cent. The company claims that castings of this grade never fall below 100,000 lbs. per sq. inch in tensile strength, and have reached as high as 130,000 lbs.

The lower grades of the metal are classed as *B*, *C*, *D*, and *E*, and contain 7½, 5, 2½ and 1¼ per cent. of aluminum respectively. They decrease in tensile strength in the order named, that of the first being about 65,000 lbs., while the last runs about 25,000 lbs. per sq. inch. There is a proportionate amount of decrease in transverse and torsional strength, elastic limit, and resistance to compression, as the percentage of aluminum is lowered, but the ductility increases in the same proportion.

The *E* grade metal will stretch nearly two-thirds of its whole length before rupture, which exceeds the elongation of pure copper by about 100 per cent.

The toughness of the lower grades of this bronze is very remarkable. It is stated that a piece of *C* grade wire can be twisted through several hundred turns before breaking. Any one who has ever had occasion to twist together two ends of iron wire, and has had them break off just at the critical moment, will fully appreciate the value and convenience of a wire which can be twisted indefinitely.

The specific gravity of the *A* grade is 7.56, that of steel being 7.88. In the lower grades, the expansion by heat, specific gravity, and power of conducting heat and electricity increase the nearer the metal approaches to pure copper.

In color, the *C* and *D* grades are the nearest to gold of any known metal, the higher grades being of a lighter color than the lower.

Even the lowest grades of the bronze resist oxidation and corrosion to a marked degree, being in this respect very much superior to iron or pure copper. The quality of thus resisting corrosion and oxidation is one of the utmost value, and is possessed to a greater extent only by gold and platinum.

The lowest grade of bronze becomes of a darker yellow color

under the action of the atmosphere, but never turns black like other bronzes or green like brass. It is not affected by salt water, soapy water, or any of the animal or vegetable fluids, and for this reason, it may become very valuable to ship builders and sanitary engineers. It is not blackened like silver by sulphuretted hydrogen or sulphur from coal gas, and is not readily attacked by the ordinary acids except hydrochloric, which dissolves out the aluminum. Alkalies, however, attack it readily, and concentrated sulphuric acid rapidly forms a coating over it, but this coating seems to protect it from further injury.

It is oxidized by the atmosphere, when in the melted state, but its susceptibility to oxidation ceases the instant the metal changes from the liquid to the solid state. On this account, it is being quite largely used for burners in vapor stoves, gas burners and tuyeres for blast furnaces. There seems to be no diminution of weight or change whatever after the metal has been kept at a bright red heat for several months.

In making castings from the bronze, it is found that the higher grades melt at a somewhat lower temperature than those containing less aluminnm. The *A* grade melts at 1700° *F*, a little higher than ordinary bronze or brass. Several precautions must be carefully observed in casting it, as it shrinks considerably and solidifies rapidly. One of the chief difficulties is the avoidance of the oxidation in the melted state when transferring the metal from the crucible or ladle to the mould. If any of this oxide gets into the casting, it appears like so much dirt and is apt to cause trouble. For further particulars and more explicit directions in regard to the manipulation of the bronze in casting, the reader is referred to the Cowles Company's pamphlet and also to a paper on the subject read by Thomas D. West before the 14th meeting of the American Society of Mechanical Engineers at New York in 1886.

All the grades of bronze except the *special* can be rolled and drawn cold, but because of their greater ductility the lower grades can be drawn cold much easier than the others. Aluminum bronze can be worked at a bright red heat as easily as wrought iron, and is the only bronze in the arts which is not "hot short," that is, brittle at a red heat. Numerous advantages arise from this fact alone. Under the tool the *A* and *special* grades work when cold, similar to machinery steel, and the lower grades like wrought iron. Rolling or working the metal in any way makes it stronger and tougher. It may be easily brazed and soldered.

The engineering purposes for which aluminum bronze may be used are numerous and varied. The *A* and *special* grades are recommended for the following: light and heavy cannon, armor plate, propellers, pump rods, valves and valves seats, cylinder linings, slide faces, mining and hydraulic machinery, pumps, especially mining pumps drawing acidulated waters or working under great pressure, turbine wheels working under high head, bearings for steel shafts running at high velocity, and many other articles where minimum weight with maximum strength are desired, and which cannot be easily forged out of steel.

The lower grades may be used for a great number of purposes, among which are the following: rudder chains, wire gauze intended to stand a red heat, gas burners, cartridge shells, dynamo hubs, locomotive fittings and tubes, sanitary appliances, tuyeres, bosh plates, and coolers for blast furnaces, wire rope, and astronomical instruments. For covering spires and domes, sheets of aluminum bronze are thought to be superior to any other metal except gold.

The *A* grade bronze is especially adapted for bearings working under extremely high pressure, as its crushing strength is equal to that of machinery steel, while at the same time it is one of the best anti-frictional metals known.

The present prices charged for the metal by the Cowles Company range from 16 to 45 cents per lb., depending upon the grade, and amount of contained aluminum. These are for Lockport, N. Y. deliveries in the form of ingots.

Through the kindness of the Cowles Company and Mr. Theodore Stevens, a graduate of Lehigh University in the Class of '86, the following full reports for two tests are presented. These tests were made at the Watertown Arsenal, under the supervision of government officers. Mr. Stevens, who is in the employ of the Cowles Company, says in regard to the test pieces:

"These two bars were rolled, which treatment makes the ductile specimen (No. 1) about 15 per cent. stronger than it would have been, had it been cast. The other is not materially affected by the rolling. The ductile one contains 8 per cent. aluminum and some silicon. The stronger contains 11 per cent. aluminum and some silicon. In our bronzes, silicon is an essential constituent. Our metal is harder than most alloys. On the reports I send you, our bronze had hardness of 10.6 to 16, while Navy Yard bronzes, tested at the same time, were 3.33 to 6.56."

By making use of the data, furnished by these reports, curves of the metal may be constructed, using unit-stresses as ordinates, and unit-elongations as abscissas, and graphic comparisons may thus be easily made of the qualities of the bronze with those of iron and steel by constructing to the same scale similar curves for the latter metals.

Ordnance Department, U. S. A.

Report of Mechanical Tests made with the U. S. Testing Machine, capacity 800,000 lbs.,

at Watertown Arsenal, Mass., October 28, 1887,

for The Cowles Electric Smelting and Aluminum Company, Lockport, N. Y.

Tests by Tension—Two Pieces Aluminum Bronze.

No. 1.

Bar, 10 in. between marks.
0.564 in. diameter.
1.15 in. " of shoulder.
Sectional area, .25 sq. in. Gauged length, 10 in.

APPLIED LOADS. Pounds.		IN GAUGED LENGTH.		
Total, pounds.	Thousands per sq. in.	Elongation, inches.	Set, inches.	REMARKS.
250	1			Initial Load.
1250	5	.0023		
2500	10	.0053		
3750	15	.0082		
5000	20	.0112		
6250	25	.0140		
7500	30	.0172		
8750	35	.0200		
10000	40	.0233		
11250	45	.0266	.0001	
12500	50	.0317	.0009	Elastic Limit=50,000 lbs.
12750	51	.0328		E = 15741000 lbs.
13000	52	.0342		
13250	53	.0367		
13500	54	.0395		
13750	55	.0424		
14000	56	.0485		
14250	57	.0538		
14500	58	.0638		
14750	59	.0721		
15000	60	.0864		
15500	62	.1200		
16000	64	.1500		
16500	66	,1900		
17000	68	.2300		
17500	70	.2900		
18000	72	.3400		
18500	74	.4400		
19000	76	.5400		
19500	78	.6800		
20000	80	.8300		
20500	82	1.0300		
21000	84	1.2900		
21500	86	1.6300		
22000	88	2.0400		
22420	89,680			Tensile Strength=89,680 lbs.
		2.9700 after rupture.		Total Elongation=29.7 per cent.

No. 2.

Sectional area, .2 sq. in. Gauged length, 2 in.

APPLIED LOADS. Pounds. Total, pounds.	Thousands per sq. in.	IN GAUGED LENGTH. Elongation, inches.	Set, inches.	REMARKS.
200	1			Initial Load.
1000	5	.0005		
2000	10	.0011		
3000	15	.0018		
4000	20	.0022		
5000	25	.0029		
6000	30	.0035	.0001	
7000	35	.0041	.0001	
8000	40	.0049	.0001	
9000	45	.0055	.0001	
10000	50	.0064	.0001	E=15625000 lbs.
10200	51	.0066		
10400	52	.0067		
10600	53	.0069		
10800	54	.0070		
11000	55	.0073		
11200	56	.0076		
11400	57	.0079		
11600	58	.0082		
11800	59	.0085		
12000	60	.0089	.0005	
12200	61	.0093		
12400	62	.0096		
12600	63	.0098		
12800	64	.0101		
13000	65	.0105		
13200	66	.0108		
13400	67	.0111		
13600	68	.0115		
13800	69	.0119		
14000	70	.0124		
14200	71	.0127		
14400	72	.0131		
14600	73	.0135		
14800	74	.0140		
15000	75	.0145		
15200	76	.0149		
15400	77	.0153		
15600	78	.0158		
15800	79	.0162		
16000	80	.0168		
16200	81	.0174		
16400	82	.0179		
16600	83	.0186		
16800	84	.0191		Probable Elastic Limit.
17000	85	.0199		
17200	86	.0206		
17400	87	.0215		
17600	88	.0225		
17800	89	.0235		
18000	90	.0246		
18200	91	.0256		
18400	92	.0267		
18600	93	.0281		
18800	94	.0299		
20000	100	.0450		
20800	104	.0750		
21600	108	.1050		
22280	111.4	.1300 after rupture.		Tensile Strength=111,400 lbs. Total Elongation=6.5 per cent.

Elongation of inch sections: .07″, .06″.

Diameter of fracture, .46″; area, .1662 sq. in.

Contraction, 16.9 per cent.

Fractured at middle of stem. Appearance, fine silky, radiating from centre punch mark which defined the inch section. Lavender color.

Correct, J. E. HOWARD,

F. H. PARKER,
L. Col. Ordnance Dept. U. S. A.
Commanding.

In conclusion, the writer wishes to express his obligations to the Cowles Company and to Mr. Stevens for their kindness in furnishing the above reports, and also for specimens of the metals themselves. He is also indebted to Mr. J. W. Richards for similar favors.

A. T. THROOP, '89.

THE GRADING OF PIG IRON.

BY FREDERICK L. GRAMMER.

Pig iron is graded differently in the North and South, though size of grain in the fracture is the governing influence in each case. In the following columns the grades are arranged so that the same quality pigs are on the same line.

NORTH.	SOUTH.
No. 1 extra.	1
1	2
2	2½
3	3
4	4
5	5
6	6
Open silver G.	Open silver G.
Close silver G.	Close silver G.

The South has another grade, *short* 3, which is almost the same as 4, and commands the same price. Hereafter, whenever 4 is spoken of, *short* 3 may be understood as being included, and, unless otherwise stated, the grades mentioned in this paper will be those of the southern classification.

The first five grades, Nos. 1, 2, 2½, 3 and 4, are termed gray pigs because of a predominance of graphitic over combined carbon. These, with the silver G., are high in silicon, because of the intense heat at which they are produced and are consequently brittle. The foundry irons, to which use all gray pigs may be put, and by which name they may be known, contain desirable amounts between 2 and 2½ per cent. of silicon. Nos. 3 and 4 of the foundry irons, provided they do not contain more than the limiting per cent. of sulphur and phosphorous, are used almost exclusively for steel rails, and are generally designated as Nos. 1 and 2, *mill*, respectively.

The means of distinguishing between these grades is the size of the grains in the surface of fracture, the size decreasing as the number of the grade increases. This is true, save with the silver

G., which are distinguished from the foundry irons by the pinkish steel gray color of the former, in contrast to the bluish steel lustre of the latter. No. 1 *pig* shows the largest grain and commands the highest price. The foundry irons are more expensive, because of the higher heat and pressure under which they are produced. The pressure and temperature of the blast, together with variations in the burden, are the instruments at the disposal of the furnace boss in charging the grades of pig.

No. 5 is a mottled iron, its fracture at once showing the anatomy. The carbon is partly combined and partly graphitic, hence the mottled appearance produced by the gray or white in the broken pig. No. 5 is used chiefly in puddling. No. 6 is white pig, in which the carbon is mostly combined, and the surface of fracture both lighter and more glassy than in the foundry or gray irons. This grade is produced at a low temperature and with heavy burden, is very brittle, extremely hard, contains but little silicon, and is used mostly in puddling. Close silver G. iron is almost useless except for those purposes where weight and economy are the elements most desired, such as iron for window and clock weights.

Such are the present grades of the pig iron market, and these grades according to the fracture are supposed (often erroneously) to contain different percentages of silicon, manganese, carbon—both combined and graphitic,—and perhaps sulphur and phosphorous, and it is the fallibility of the method of grading which has suggested an inquiry into the subject by several writers in the *Iron Age*. The disadvantages of fracture classification seem quite numerous, but we can judge of them for ourselves.

Rust on the surface of fracture often wholly hides the lustre and size of the grain, more often hiding it sufficiently to deceive the buyer and yet leave him no doubts as to the accuracy of his judgement. A chill on the surface by too wet sand creates a different sized grain near the exterior of the pig. Rapid flowing in the main runner and sows affects the size of the grain. It is this influence which is often given as an explanation of the same pour (casting) giving three or four different grades. Besides these irregularities in the cross section of different pigs from the same pour, few cross sections of the same pig exhibit a homogeneous structure, large grains being distributed here and there among the small. This lack of uniformity requires an average to be taken and here is the latitude of which the gradesman takes

advantage. It is fortunate for him there is such a loop hole. His position is no sinecure, as three parties have to be satisfied with his decisions. The furnace man wishes as much No. 1 as possible, a large proportion of the casting as this grade being greatly to his credit. I have heard a furnace boss grumble because iron which he considered No. 1 was classed as No. 2. Then the purchaser's and company's side of the question have to be considered. If the market demands No. 2, a slightly disordered conscience, such as most gradesmen have, finds no insuperable obstacle to calling Nos. 2½ and 3 as of that grade.

Another witness that differences in structural arrangement do not necessarily result from unlike compositions is, that a pig broken in three places has been known to exhibit as many different grades. And finally, before considering the claims and advantages of fracture grading, it may be interesting to know that the differences in the scales of classification employed in the North and South, slight as they are, have been the cause of considerable loss to a Southern firm ignorant thereof. Fracture has, however, some strong arguments in its favor and some of the objections brought up can be easily answered. Rapidity of execution is now sought after in all the sciences; no chemical process can rival the time occupied in glancing at a cross section. A man who is deceived by a rusty fracture deserves his loss for not having the sense to break the pig and examine a clean surface. Chilling with too wet sand occurs but rarely with good furnace men, and even when it does occur, is of slight importance. Rapidity of flow can easily be governed. It is an advantage of which all can make use, and different grades from the same pour result less from this cause than from chilling in cooling. Rapidity of flow allows the iron to reach the mould soon and hence in a hot condition. The higher the temperature, the longer the time necessary for cooling, and slowness of cooling always occasions large grains. The fact of three different fractures from the same pig is something of a curiosity, and is quoted as such. The raising and lowering of grades to accommodate the market is not a very heinous offence, for the actual differences between Nos. 1, 2 and 2½ are very small indeed. I mention these grades because they run into each other and there is but little variation in the cost of their production.

The differences in the grading practiced at the North and South can be understood in five or ten minutes, though they should be done away with. These are the main objections to fracture grad-

ing and some of the answers that could be given. As stated before, a glance reveals whether the carbon is combined or graphitic, and which predominates, when carbon enters in both forms, and also tells quite accurately the relative amount of silicon.

As for sulphur and phosphorous, their percentages are predetermined more by the nature of the charge and ore than by anything else, and samples of different grades from the same ore and charge show but little variation in these elements. It is because the same grade from different ores and furnaces may contain different percentages of phosphorous and sulphur that an analysis is necessary for mill irons. In the acid Bessemer process practiced in America, there must be not over one-tenth of one per cent. of phosphorous in the mill pig used. For some fine grades of steel, the per cent. of silicon in the pig has to be accurately determined, but for ordinary foundry use, nothing has as yet proved so satisfactory as fracture grading.

Whatever decision may be finally reached in the investigation of the comparative merits of fracture and analysis grading is uncertain, but the inquiry undertaken for this purpose cannot fail to be of advantage to all, in making familiar the effect of various constituents upon pig iron. F. L. GRAMMER, '89.

ABSTRACT OF PROCEEDINGS.

SEPT. 13, 1888.—President Villalon in the chair at 20 o'clock, with eight members present. The following gentlemen were elected to membership: Mr. W. H. Woods, '87; Messrs. Ayres, Bates, Butterworth, W. A. Cornelius, Johnston, Carson, Grammer, Morrow, Porter, Rogers and Schwartz from '89; and Messrs. Baily, Barrett, Beazell, Cardenas, Clarke, Coates, Cope, Davis, De Moyer, Detweiler, F. E. Fisher, F. R. Fisher, Greene, Hearne, Hoover, Howe, Nauman, Phillips, Sherman, Stone, Van Cleve and Weihe from '90.

SEPT. 27.—The meeting was called at 19.20 o'clock by President Villalon with twenty-six members present. The following were elected members from '90: Messrs. Alcott, Coxe, Fink, Fleck, Gibbs, Goodman, Harley, Hollinshead, Houston, Howard, Kulp, Kurtz, Landis, Litch, Mercur, Neumeyer, Perkins, Pratt, Prindle, Riddick, Round, Shoemaker, Stevenson, Stout, Straub, Thomson, Tomkinson, Turner, Webb, Williams and Wright. The following were elected associate members: Messrs. Anderson, Barrios, Burden, Doolittle, Hayes, Heindle, Kennedy, H. Lefevre,

Miller, H. T. Morris, Paine, Rafferty, Vander Horst, Wendle, Whitney and Zahniser from '91. Mr. W. V. Kulp, '90 was elected editor of the JOURNAL from the Junior class. The thanks of the society were tendered the President of the University for the use of a room in Christmas Hall. The following papers were read: "Grading of Pig Iron," by Mr. F. L. Grammer, '89 and "Slag Bricks," by Mr. J. B. Wright, '89. A. W. STOCKETT, Sec'y.

EDITORIALS.

BY some unaccountable oversight, the article in No. 3, Vol. III., on "Burning Petroleum as a Fuel," was not credited to its author, Mr. Lester P. Breckenridge, Instructor in Mechanical Engineering in the Lehigh University. Our attention was but recently called to this omission and we hasten to give the proper credit.

MR. FRED. P. SPALDING, '80, late instructor in Civil Engineering in the University, has accepted the position of Assistant Engineer in the Third District of the Mississippi River improvements. His temporary address is, U. S. Engineer Office, 106 Madison St., Memphis, Tenn. By the departure of Mr. Spalding the University loses a faithful and efficient instructor. The JOURNAL wishes him a large measure of success in his new field of work.

THE new staff of the ENGINEERING JOURNAL must make its preliminary bow in the form of an apology for the delay in sending out the last number to those subscribers who were students at the University and had returned to their homes when the JOURNAL was mailed. Without endeavoring to locate the cause of the delay, we hope that No. 4, Vol. III, is now in the hands of every subscriber. If any one has failed to receive his copy, please notify the Business Manager at once.

WE are pleased to announce that the Engineering Society has secured Room 11, Christmas Hall, for the exclusive use of the editors of the JOURNAL and the officers of the Society. This is an advantage over last year, when our meetings were held anywhere and everywhere, and will greatly facilitate the work of publication.

In moving into our new quarters, we discovered a small number of complete sets of the JOURNAL, together with several hundred copies of some numbers. The sets will be sold only as such at the regular subscription rates, and odd numbers may be obtained from the Business Manager for fifteen cents each. As we have but few copies of some numbers of the JOURNAL, those wishing to complete their sets should do so at once.

It was announced in the last number that the subscription price of the JOURNAL had been advanced from fifty cents to one dollar per annum. This advance has been necessitated not only by the comparatively small subscription list, but also by the wish to increase the size of the JOURNAL and add to the number of its illustrations, hoping thereby to promote its usefulness. In order to do this, we need the hearty co-operation of all students and alumni in the form of subscriptions and literary matter. The former may be handed to the Business Manager, and the Editors ask for, and will gratefully acknowledge any articles bearing upon the engineering professions. We have no cause to feel dissatisfied with the success of the JOURNAL in the past, and in the future will endeavor to maintain the standard now reached, and to this end again ask the assistance of all friends of the Society and the University.

We are pleased to note the increased demand for the JOURNAL by parties not immediately connected with the University. Orders have recently been received from a New England firm for copies containing Mr. Breckenridge's paper on "Burning Petroleum as a Fuel," and other copies have been similarly in demand. Several of the JOURNAL'S papers have been republished in the leading technical periodicals, the last being Mr. Paret's, on "The Construction of a Skew or Spiral Arch," which will shortly appear in the *Engineering News*.

A large number of changes have been made this year in the instructive force of the University, and, as usual, the Department of Engineering is affected. In the School of General Literature, Prof. W. A. Robinson, M. A., fills the chair made vacant by the resignation of Prof. W. A. Lamberton, now of the University of Pennsylvania, and Mr. R. M. Huse has succeeded Mr. W. K. Gillett as Instructor in Modern Languages. Prof. Robinson graduated from Princeton in the class of 1881, and since then has been Professor of Greek at Marietta College, Ohio. Mr. Huse was formerly a student at Amherst, but for the past fifteen years has resided in France. He has received an honorary A. M. from Hobart College. In the School of Technology, Mr. J. J. Flather, Ph. B., Sheffield Scientific School, '85, fills the place of Mr. E. F. Miller, formerly Instructor in Mechanical Engineering, but now with R. D. Wood & Co., Camden, N. J. Mr. Flather is favorably known by many articles in the technical papers, and was for a number of years engineer in works at Rochester, N. Y.

The return of Prof. Frazier from Europe renders a successor to Mr. S. C. Hazleton unnecessary, Mr. Richards carrying on the latter's work. Two vacancies have occurred in the Department of Chemistry through the resignations of Mr. Mackintosh and Mr. Lake. The place of the former is filled by Mr. G. M. Richardson, '86, as Instructor in Quantitative Analysis, and Mr. Lake has been followed by Mr. L. R. Lenox, Ph. C., of the School of Mines, Columbia College, New York, as Instructor in Qualitative Analysis and Assaying. Mr. Richardson, for the past two years, has been pursuing a course of post graduate study in Chemistry at Johns Hopkins University, Baltimore, Md., and Mr. Lenox was, until recently, in the laboratory of the Bethlehem Iron Company. We welcome these gentlemen, and assure the friends of the University that her efficiency has been in no way impaired by these changes.

ALUMNI NOTES.

1870.

—Wm. J. Kerr, A. C., is Mechanical Engineer for the H. B. Smith Machine Co., 925 Market St., Philadelphia, Pa.

1871.

—Waldron Shapleigh, A. C., is chemist for the Welsbach Incandescent Gas Light Company, Gloucester, N. J.

1872.

—D. P. Bruner, C. E., is Civil Engineer, Architect and Builder, at 4834 Morris St., Germantown, Pa.

1875.

—Chas. J. Bechdolt, C. E., is the Assistant Engineer of Middle Division, Penna. R. R. His address is 924 N. Third St., Harrisburg, Pa.

—F. S. Pecke, C. E., is with Moffett, Hodgkins & Clarke, Engineers and Contractors, 19 Clinton St., Watertown, N. Y.

—A. E. Meaker, C. E., Instructor in Mathematics at the Lehigh University, was elected a member of the American Association for the Advancement of Science at the Cleveland meeting in August.

1878.

—Wm. Hazlett, M. E., is an Architect, office 151 Broadway, New York.

—Milnor P. Paret, C. E., has contributed a paper to the *Engineering News* entitled "From Preliminary to Track—Points in Railroad Construction for Young Assistant Engineers." Its publication was begun in the number dated August 11, and concluded in that of September 1. His paper on "The Construction of a Skew or Spiral Arch," which appeared in the JOURNAL OF THE ENGINEERING SOCIETY for February, 1888, will shortly be republished in the *Engineering News*. Mr. Paret's address is 104 West Saratoga street, Baltimore, Md., his position being that of Assistant Engineer for the Harbor Board.

—H. F. J. Porter, M. E., was married to Miss Rosalie Smith, of Morristown, N. J., on August 27, 1888.

1879.

—James S. Cunningham, M. E., one of the Honorary Alumni Trustees of the Lehigh University, is at present the Mining Engineer of the Berwind-White Coal Mining Co., Punxsutawney, Pa.

1880.

—Abram Bruner, E. M., is a Division Engineer on Lynchburg Division of the Norfolk & Western Railroad, at Roanoke, Va.

1881.

—Charles W. Gray, A. C., is located at Oakland, Fla., occupying the position of Auditor for the Orange Belt Railroad.

1882.

—L. O. Emmerich, E. M., is Superintendent of the Humboldt Colliery at Hazleton, Pa.

—Elmer H. Lawall, C. E., was married, on June 14, to Miss Carrie E., daughter of George John, a prominent coal operator residing at Audenried, Pa. Mr. Lawall is a Civil and Mining Engineer.

—Eugene Ricksecker, C. E., has been appointed Engineer and Superintendent of the Puget Sound Creosoting Co , at Seattle, Wash. Ter. We extract the following from a local paper:

SEATTLE, Aug. 7.—Immense creosoting works are being located here. Eugene Ricksecker, formerly with the United States geological survey, and for the past year associated with large creosoting works at Wilmington, Del., and Fernandina, Fla., has just arrived here to undertake the management of the Puget sound works. A plant is now building at the Richmond locomotive works, to cost $125,000, to be delivered within ninety days. Ten acres of land on the water front near this city has been purchased, and the whole will be needed for the plant and lines of railroad connecting therewith. A company has been organized under the name of the Puget Sound Creosoting Works. The capacity of the works is to be 109 piles a day, of lengths varying from fifty to one hundred feet. Nearly all the work will be done by machinery. Iron cars holding six logs will be drawn from the logging camps directly into immense tanks, where the timbers will be submitted to pressure by steam to remove the sap, and then creosote will be forced into the fibers with a pressure of 250 pounds to the square inch. This system is endorsed by the American and Royal societies of civil engineers. The Seattle works will be the only one of the kind on the Pacific coast. The big works at Wilmington have been running eight years, and those at Fernandina two years. Great success has attended the work there, and no doubt the Puget Sound works will have abundant success.

—Martin Wittmer, E. M., is a Mining Engineer at Glen Shaw, Allegheny Co., Pa.

1883.

—H. A. Butler, B. S., is the General Manager of the Chapman Standard Slate Co. at Chapman Quarries, Pa.

—T. J. Donahue, A. C., is employed in the laboratory of the Bessemer Steel Works at Troy, N. Y.

—A. E. Forstall, M. E., has recently been appointed Manager of the North station of the Chicago Gas Light and Coke Co., Chicago, Ill.

—W. T. Goodnow, C. E., is located at Nashville, Tenn., being General Superintendent for the Scovil & Irwin Constructing Co.

—George G. Hood, C. E., is in the Engineer's Office of the Central Railroad of New Jersey at Elizabeth, N. J.

—Geo. S. Patterson, E. M., is located at Anniston, Ala., as a Mining and Civil Engineer.

1884.

—J. R. Engelbert, C. E.. is the Assistant Engineer of the Mineral Ry. & Mining Co., Shamokin, Pa.

—William B. Foote, E. M., is at Bessemer, Bibb Co., Ala., being Assistant Superintendent of the blast furnaces for the DeBardeleben Coal and Iron Co.

—J. A. Jardine, E. M., has accepted the position of Superintendent of the Coal City Coal and Coke Co. at Jasper, Walker Co., Ala.

—H. K. Myers, C. E,, is the Manager and Mining Engineer of the Kittanning Coal Co. and the Tipton Coal and Coke Co. His address is Tyrone, Pa.

—Albino R. Nuncio, M. E., is the Third officer of the Fourth section of the Department of Public Works of the Mexican Republic, City of Mexico.

—Murray Stewart, M. E., is in the Test Department of the Pennsylvania R. R. Co., at Altoona, Pa.

—James A. Watson, C. E., is an Assistant Examiner in Room 98 of the U. S. Patent Office at Washington, D. C.

1885.

—F. B. Petersen, C. E., is in the U. S. Mint at Denver, Col.

—John B. Price, C. E., is the Teller in the First National Bank, Hazleton, Pa.

1886.

—Max. S. Hanauer, A. C., is the Manager of the Union Assay Office at Salt Lake City, Utah.

—William A. Lydon, E. M., is Assistant Engineer on the construction of the South Chicago water supply tunnel. The tunnel is to be six feet in diameter, to extend six miles under the southern portion of the city and four miles into the lake where the crib will be stationed. The work is to be completed in three years.

—Chas. A. Junken, C. E., is a member of the firm of Jenness & Junken, Mining experts. His address is, Box 266, Black Hawk, Col.

—P. D. Millholland, C. E., is an Assistant Engineer on the George's Creek and Cumberland R. R., Cumberland, Md.

—Wm. H. Sayre, Jr.. is at Snoqualmie, King Co., Wash. Ter.

—Jos. K. Searls, B. M., is Mining Engineer for the Woodstock Iron Co., at Anniston, Ala.

—E. S. Stackhouse, E. M., is a dealer in mine timber, Shickshinny, Pa.

—Priestley Toulmin, B. M., is a Mining Engineer for the Sloss Iron and Steel Co., of Birmingham, Ala., with headquarters at Coalburg. Ala.

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—F. R. Dravo, M. E., is a draughtsman for the Latrobe Steel Works at Latrobe, Pa.

—J. B. F. Hittell, C. E., is in the office of the assistant to the Division Engineer, Chicaga, Santa Fe & California R. R. His address is 416 N. Cherry St., Galesburg, Ill.

—John M. Howard, M. E., is connected with the new plant of the Latrobe Steel Works.

—William F. Kiesel, Jr., M. E., is located at Altoona, Pa. He is a draughtsman in the Car Shops of the Pennsylvania Railroad.

—J. W. La Doo, C. E., is an assistant to C. W. Knight, Hydraulic Engineer, Rome, N. Y.

—James A. Morrow, C. E., is the Hydraulic Engineer for the American Water Works and Guarantee Co., Limited, Lewis Block, Pittsburgh, Pa.

—R. H. Phillips, C. E., is engaged on a special survey by the United States Geological Survey, in Arizona.

—Rufus K. Polk, E. M., is the Chemist and Engineer for the Montour Iron and Steel Co. at Danville, Pa.

—Mason D. Pratt, C. E., is with the Johnson Steel Street Railway Co., of Johnstown, Pa., and is now putting down a track in Washington, D. C. He was declared elected a Junior Member of the American Society of Civil Engineers at the meeting in September.

—G. T. Richards, C. E., is the Chief Engineer of the McKeesport and Belle Vernon, Railroad, Pittsburgh, Pa.

—Edward P. Vankirk, E. M., is also employed by the McKeesport & Belle Vernon Railroad, Pittsburgh, Pa.

—John W. Scull, M. E., died August 14, at the residence of his parents, 818 Girard Avenue, Philadelphia, Pa., of typhoid pneumonia, after an illness of but six days. Hopes were entertained of his recovery until shortly before death came. He was engaged in the manufacture of machinists' supplies.

—Frank S. Smith, A. C., has charge of the Lamp Department of the Westinghouse Electric Light Co., Pittsburgh, Pa.

—Frank Williams, E. M., has resigned his position at Johnstown, and is now located at Pittsburgh, Pa.

—N. J. Witmer, C. E., is in the employ of the Norfolk & Western Railroad, his address being Ceredo, Wayne Co., W. Va,

—G. F. Yost, M. E., is a Draughtsman for the C. M. Hunt Co., at W. New Brighton, Staten Island, N. Y.

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—George R. Baldwin, M. E., is with the Brush Electric Light Co., his address being 898 Wilson Avenue, Cleveland, O.

—W. D. Beatty, C. E., is a Draughtsman in the office of the Phoenix Bridge Co., Phoenixville, Pa.

—Wm. Bradford, C.E., is on an engineer corps of the Pennsylvania Railroad, at Dover, Del.

—C. N. Butler, C. E., is with the Lehigh Valley Railroad at Mauch Chunk, Pa.

—A. T. Bruegel, M. E., has been appointed an Instructor in Mathematics and Drawing in the Cogswell Polytechnic College, San Francisco, Cal., and entered upon the duties of his new position in August.

—M. L. Byers, C. E., is an Assistant Engineer on the Erie & Ashtabula Division of the Pennsylvania Railroad. His present address is Leslie House, New Castle, Pa.

—Geo. H. Davis, C. E., is an Assistant Engineer for the Vermont Marble Co., at Proctor, Vt.

—P. H. DeWitt, C. E., and M. V. Domenech, C. E., have accepted positions on the Engineer Corps of the Lehigh Valley Railroad. Their address is: Office of the Principal Assistant Engineer, Jersey City, N. J.

—G. S. Franklin, M. E., is with G. M. Steinman & Co., Hardware Dealers, Lancaster, Pa.

—S. W. Frescoln, C. E., has returned to Lehigh University to pursue a post-graduate course in Civil Engineering and Mathematics.

—H. Hardcastle, M. E., is in the Lehigh Valley Car Shops at Hazleton, Pa.

—G. A. Hart, M. E., is with the Bethlehem Iron Co.

—J. S. Mack, C. E., is on the Engineer Corps of the Lehigh Valley Railroad. His address is Hazleton, Pa.

—W. A. McFarland, M. E., has been appointed an Inspector of United States Harbor Improvements. Address: Box 102, Station A, New York City.

—Howard L. McIlvain, A. C., is a member of the firm of Wm. McIlvain & Son, Manufacturers of Boiler Plate, Reading, Pa.

—H. S. Miner, A. C., has entered the employ of the Welsbach Incandescent Gas Light Co. at Gloucester, N. J., as Assistant Chemist.

—H. S. Neiman, A. C., is Chemist for the Albany Aniline Co., 145 N. Pearl St., Albany, N. Y.

—H. Palmer, C. E., has accepted a position as Draughtsman for the Edge Moore Iron Co. at Wilmington, Del.

—F. W. B. Pile, E. M., is with the Bethlehem Iron Co.

—C. E. Raynor, C. E., is in the office of the Chief Engineer of the Lehigh Valley Railroad at Mauch Chunk, Pa.

—Osmond Rickert, C. E., is an Engineer with Coxe Bros. & Co., Eckley, Pa. His address is Hazle Brook, Pa.

—E. H, Shipman, C. E., has established an office as Civil Engineer and Surveyor, in the Sloyer Building, E. Third St., South Bethlehem.

—W. A. Stevenson, M. E., has accepted the position of Assistant Master Mechanic of the Pennsylvania & New York R. R. Shops, at Sayre, Pa.

—H. A. J. Wilkens, E. M., is studying Mining and Mineralogy at Freiburg, Germany.

—Edw. B. Wiseman, C. E., is an Assistant Supervisor of the Philadelphia & Erie Division of the Pennsylvania R. R. His andress is 392 Maynard St., Williamsport, Pa.

—S. Yamaguchi, C. E., is with the Pennsylvania Railroad Co. N. W. System, at 94 Sandusky Street, Allegheny City, Pa.

—J. R. Villalon, Class of 1889, the President of the Engineering Society, is a Junior Member of the American Society of Civil Engineers.

—The following officers of the Alumni Association were elected at the Annual Meeting, on June 20: Charles Bull, *President;* George A. Jenkins and Robert P. Linderman, *Vice-Presidents;* H. S. Jacoby, *Secretary and Treasurer*, and Wallace M. Scudder, *Honorary Alumnus Trustee.* The "*Proceedings*" of the Association are now in press and will be issued very soon.

—A circular letter signed by G. T. Richards, E. P. Van Kirk and Frank Williams was sent to Lehigh graduates residing in Pittsburgh, Pa. and vicinity, calling a meeting to be held at Parlor C, Hotel Anderson, Pittsburgh, Pa., August 4th, for the purpose of forming an Alumni Association of Pittsburg. At the meeting twelve graduates were present, and letters and telegrams were received from others showing considerable interest in the scheme. A committee consisting of G. T. Richards, *Chairman*, Charles L. Taylor, J. H. Paddock, J. F. Merkel and Frank Williams was appointed on Constitution and By-Laws and on nominations for permanent officers. Owing to a number of men being out of the city during the summer, the committee will not report until the middle of October, when a meeting will be called for that purpose.

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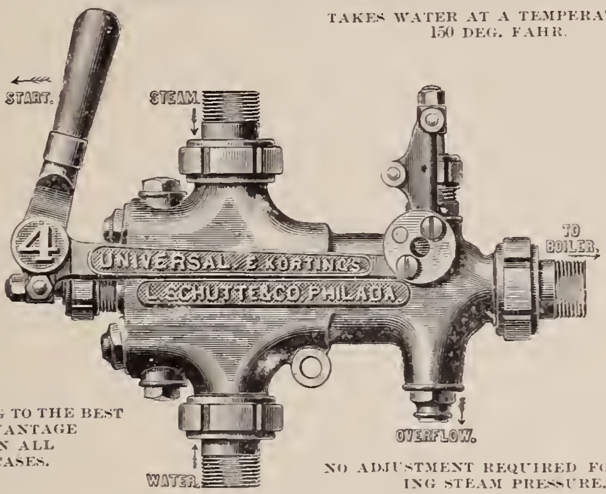

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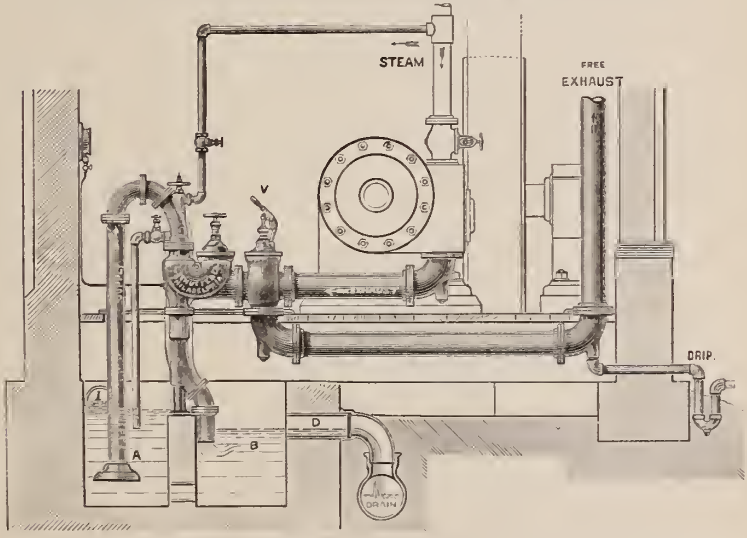

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